Cerebellum and cognition – viewed from philosophy of mind

M. FRINGS, M. MASCHKE & D. TIMMANN

Department of Neurology, University of Duisburg-Essen, Germany

Abstract
Traditionally, it is believed, that the primary function of the cerebellum is to coordinate movement. During the past three decades, it has been controversially discussed, whether the cerebellum may also contribute to cognition and mental states like emotions. In this paper, no position relating to this controversy will be taken. Instead, the hypothesis of non-motor functions of the cerebellum will be viewed from the position of the philosophy of mind. The remarkably uniform microscopic structure and neuronal networks of the cerebellum have led to computer analogies by several authors. The main idea of functionalism, i.e., a theory within the philosophy of mind, is that the mental relates to the physical as computer software does to hardware. This raises the question, whether a cerebellar contribution to cognition and mental states would support functionalism in the philosophy of mind. No support of functionalism could be found in this study, investigating the classical philosophical arguments pro and con functionalism such as those of multiple realizability, the Chinese room and the explanatory gap, while taking the results of cerebellar research into account. On the other hand, philosophical reflection suggests a careful use of the phrases “cognitive dysmetria” (Andreasen et al. Proc Natl Acad Sci USA. 1996;93:9985–90) in the context of mental illness and of “dysmetria of thought” (Schmahmann Arch Neurol. 1991;48:1178–87). According to the argument of the explanatory gap there is at present little support for the assumption that the phenomenal experiencing of an altered emotion can be reduced to the dysmetria of movement.

Key words: Cerebellum, cognition, philosophy of mind

Introduction
According to the classical doctrine of neurophysiology, the cerebellum is exclusively involved in the coordination of movement of the limbs, trunk, speech musculature and the eyes (1). Compared to the cerebrum, the cerebellum has a very set structure with conspicuously uniform neuronal networks. It has been proposed, that the cerebellum functions like a “neuronal machine” which performs a common type of computing function (2,3). Moreover, in recent years there has been a controversial discussion, as to whether or not the cerebellum is also involved in cognitive processes that are independent of movement (4–7). In addition to the cognitive processes, changes of mental states, such as emotional disorders, have also been proposed in some cerebellar lesion studies (8–10). In addition, structural and functional changes of the cerebellum have been demonstrated in psychiatric disorders such as autism and schizophrenia (11–13).

On the one hand, we ask what consequences for our general understanding of the relation between the human brain and mind would derive from a hypothetical evidence for a cerebellar involvement in cognition and emotion. On the other hand, we ask which contribution to cerebellar research the philosophy of mind can make.

If one attempts to ignore the dualism of our pre-scientific daily experiences, i.e., our intuitive distinction of phenomena of the physical and mental world, how can it be explained that mental phenomena can arise from the activity of a vast number of nerve cells. If, on the other hand, one assumes that there are two different entities for brain and mind, the question of their interaction with one another becomes relevant. The philosophy of mind is concerned with the relationship between phenomena of the brain and the mind, also traditionally designated as the mind-body problem. In a simplified classification, there are four different approaches: dualism, non-reductive physicalism, eliminative physicalism and reductive physicalism. Dualism originates from two different states, the mental and physical, which can occur independently.
of one another. In other words, dualism tries to prove the independence of mental states (14). Non-reductive physicalism permits an identity of physical and mental states, however, adheres to an irreducibility of the levels of description (15). A particular mental event, e.g. a certain painful event that occurs to a person, is identical to a specific physical event in their brain. Nevertheless, the description or explanation of pain cannot be reduced to the neuronal event. Eliminative physicalism asserts that mental phenomena can be eliminated without a trace, as they represent mistaken basic assumptions deriving from our everyday psychology (16). Accordingly, at some point our descendants would relinquish the use of terminology relating to mental states, such as thoughts or emotions and instead refer only to neuronal processes. Reductive theories in general suppose that complex phenomena, theories or meanings can be reduced to or explained by more fundamental phenomena, theories or meanings (17). Reductive physicalism tries to lead the reality of the mental back to the physical.

One example of reductive physicalism is the position of functionalism. In functionalism, the brain is seen as a symbolic working machine, whereby the mental relates to the physical, like computer software does to hardware. Therefore, in functionalism mental states are multiply realizable, not only by a human brain but also by a form of artificial intelligence, e.g. a computer. Beside Hilary Putnam, who later clearly distanced himself from all functionalistic theories (18,19), David Lewis, among others, developed this position further (20).

A connection between cerebellar research and the philosophy of mind emerges with the following point: The cerebellum, which is known for its conspicuously uniform microscopic structure and neuronal networks, has led to computer analogies by several authors. Moreover, an involvement of the human cerebellum in cognition and emotion has been brought forward. In functionalism the mental relates to the physical, like computer software does to hardware. Here the question arises, whether or not cognitive or emotional functions of the cerebellum – considering that the cerebellum could possibly be replaced by a computer – would support the position of functionalism in the philosophy of mind. To answer that question, this study investigates the classical arguments of the philosophy of mind pro and con functionalism, such as multiple realizability of mental phenomena (18), John Searle’s argument of the Chinese room (21) and the explanatory gap between neuronal and mental processes (22), while taking the results of cerebellar research into consideration. Furthermore, the argument of the explanatory gap was applied to the popular phrases “dysmetria of thought” (9,23) and “cognitive dysmetria” (13,24), which have been employed to describe non-motor symptoms in cerebellar dysfunction.

### Cerebellar research and functionalism

In this section, some examples of computational models in cerebellar research shall be provided, which could possibly support functionalism in the philosophy of mind. Regarding its uniform structure and its involvement in motor function, the term “neuronal machine” in particular has been used in Anglo-Saxon literature in association with the cerebellum in the past decades. The term became prevalent after the publication of a report from the neurophysiological congress “The Cerebellum as a Neuronal Machine” 1967 in Tokyo by Eccles, Ito and Szentágothai (3). David Marr, who developed an influential mathematical model of cerebellar function on the basis of this report, was a founder of the discipline of computational neuroscience, which itself was mainly influenced by functionalism (25). Masao Ito introduced the popular theory, that the cerebellum consisted of a multitude of similar functional units each consisting of few cells and nerve fibers, which he called “cerebellar microcomplexes” and compared them to computer chips (26,27). He assumes the fundamental tasks of the “cerebellar microcomplexes” to be equivalent for both motor and non-motor functions. Henrietta C. and Alan L. Leiner also spoke of “cerebellar hardware” and “software capabilities” of the control circuit between the cerebellum and the cerebrum, which make communication possible in an internal language (28). Jeremy Schmahmann called the combination of limited visual-spatial, speech and executive functions and an inappropriate control of emotions in patients with isolated cerebellar disorders “cerebellar cognitive affective syndrome” (8). In further publications he called the underlying concept “dysmetria of thought” (9,23), equivalent to dysmetria, understood as a disorder of targeted movements of the extremities. A disturbance of the modulation of movement, cognition, or emotion occurs depending on which area of the cerebrum is linked with an area of the cerebellum. The group of Nancy Andreasen designated the mood disorders that occur with schizophrenia, and formal as well as contextual thought disorders as “cognitive dysmetria” (13,24). Correspondingly they demonstrated morphological changes of the cerebellum in patients with schizophrenia (12), but also impairment in cerebellar function with the help of functional imaging of the brain (13). The term dysmetria is well-known from motor behavior and means the inability to control the range of movements. By using dysmetria in the context of cognition or thought, it is suggested to be the tertium comparationis of disturbances of cognition or thought on the one hand and of the motor system on the other. Dys - metria implies, that mental states are comprehensible by metrical masses. Whether these computational considerations in cerebellar research give evidence for functionalism in the philosophy of mind will be considered in the following.